The genus *Metacyclops* Kiefer in Australia (Crustacea: Copepoda: Cyclopoida), with description of two new species

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Abstract – Two new species of the genus *Metacyclops* Kiefer, 1927 are described from subterranean waters of Western Australia, one from the Kimberley region and the other from the Pilbara region. They both belong to the *"trispinosus"*-group, which has a clear Eastern Gondwana connection and the centre of diversity in Australia. A phyletic tree of this group in Australia is proposed. *Metacyclops kimberleyi* sp. nov. is distinguished from other members of the group by at least two autapomorphies: the exceptionally long dorsal seta on the caudal rami and the maxilliped with only seven armature elements. The only clear autapomorphy of *M. pilbaricus* sp. nov. seems to be its unusual body shape. An antenna without exopod and the second endopodal segment of this appendage with only six setae is a synapomorphy that suggests a close relationship between these two new species. As the genus *Metacyclops* in Australia already has seven valid species, a key to aid in their identification, as well as a map of their distributions, are presented.

INTRODUCTION

At the beginning of the last century the famous Norwegian carcinologist G. O. Sars described *Cyclops arnaudi* based upon material collected by O. A. Sayce in 1901 from a swamp at St. Arnaud in Victoria (Sars, 1908). This species later became the first Australian representative of the genus *Metacyclops*, which was initially established as a subgenus of the genus *Mesocyclops* Sars, 1914 by Kiefer (1927). More than half a century after *Metacyclops arnaudi* was first described, intense investigation of the limnological characteristics of many Australian inland surface waters yielded numerous invertebrate specimens (Bayly, 1964; Bayly and Williams, 1964; 1966a; 1966b). Cyclopoid copepods from those studies were sent for identification to F. Kiefer in Germany, who reported *M. arnaudi* for the second time from two lakes in Victoria (Kiefer, 1967) and also described a new subspecies of this species from a lake in South Australia. However, recent reexamination of that material by Fiers (2001) showed that Kiefer (1967) was not dealing with *M. arnaudi* at all and, furthermore, transferred both taxa into the newly described genus *Meridiecyclops*. Unfortunately, the type material of *M. arnaudi* is no longer available (Hamond, 1987), so the original description of Sars (1908), with its fine illustrations, is all that was left of the first Australian *Metacyclops*. An unnamed and as yet undescribed species of *Metacyclops* was reported by Timms and Morton (1988), but this genus does not appear to have a significant diversity in Australian surface waters, and certainly

nothing that could be compared with other continents of the Southern Hemisphere (see Dussart and Defaye, 1985).

Australian subterranean waters, on the other hand, were not investigated systematically until the last decade (Humphreys, 2001). Unexpectedly, the groundwater calcrete aquifers in the Australian arid zone come to the attention of stygobiologists and systematists on account of the diverse obligate stygofauna that is being found there by W. F. Humphreys and his colleagues from the Western Australian Museum (Humphreys, 1993). An unfolding plethora of stygal biodiversity has been found, including a number of higher order taxa variously new to science (e.g. Wilson and Ponder, 1992; Poore and Humphreys, 1992; 1998; Yager and Humphreys, 1996; Danielopol *et al.*, 2000; Jaume and Humphreys, 2001; Jaume *et al.*, 2001). The freshwater cyclopoids collected during that period were sent for identification to G. L. Pesce and his colleagues in Italy, who described *Metacyclops mortoni* from Cape Range peninsula and the Ashburton River, as the first subterranean representative of this genus in Australia (Pesce *et al.*, 1996). This species was later found at two additional localities in the Pilbara Region (Port Hedland and Cossack near Karratha) by De Laurentiis *et al.* (1999). Two years later, the same authors (De Laurentiis *et al.*, 2001) assigned two other cyclopoid species from Western Australia to the genus *Metacyclops*. The first one, *M. fiersi*, was described as a new species from three bores near Eneabba, while the second one was reported as *M.*

cf. monacanthus Kiefer, 1928 from a number of bores at Paroo Station in the Murchison Region. In my recent study of the subterranean copepods from the Murchison Region (Karanovic, 2004) *M. fiersi* was found at 24 additional localities, but it was also transferred into the newly described genus *Fierscyclops*. De Laurentiis *et al.* (2001) noticed some differences between their material and the original description of *M. monacanthus* (Kiefer, 1928), which was known only from New Zealand (Kiefer, 1928), but they made a compromise and assigned it provisionally as *con forme*. I studied that species from 44 different localities from the Murchison Region and have found a number of differences between it and the New Zealand representative (although the type material was not examined), so it was described as a new species (*M. laurentiisae*) in Karanovic (2004). In the same monograph two other new species of the genus *Metacyclops* were described (*M. superincidentis* and *M. pilanus*) and one new group of species, with the clear Eastern Gondwana connection, was established. In this paper two new species from the same group are described, one from the Kimberley, the other one from the Pilbara regions of Western Australia.

Together with the two new species, the genus *Metacyclops* has now seven representatives in Australia. At the end of this paper a key to aid in their identification and a map of their distributions are presented.

MATERIAL AND METHODS

Samples were collected with haul-nets (mesh size 250 or 350 micrometers) from groundwater monitoring bores that are made by mining companies for the purpose of water monitoring. Sometimes they are originally made for water abstraction or mineral exploration and later converted into monitoring bores. They are usually 10 to 20 cm in diameter, and may be lined entirely, or in part, by PVC tubing (the casing). This tubing may be open only at the bottom, or it may be pierced at one or more levels by holes of various sizes, referred to as "slots". The top may be securely capped or entirely open to the elements. Haul-nets are actually simple plankton nets of a different size suitable for the bore, which can range from 30 to 180 mm in diameter. Weighed nets were lowered down into the bore with one bottle screwed on its distal part than hauled through the water column, usually a number of times. All samples were sorted while alive under a dissecting microscope and the copepods were then fixed in 70% ethanol and assigned a field number (prefix BES). Many bores established for hydrogeological work, mineral exploration and water monitoring have prefixes or suffixes of relevance only to that drilling program. These codes are cited in the examined material for

both species to aid specification of the location.

Specimens were dissected in Faure's medium, which was prepared following the procedure discussed by Stock and Vaupel Klein (1996). Dissected appendages were covered with a coverslip. For the urosome or the whole animal two human hairs were mounted between the slide and coverslip, so the parts could not be squashed. By moving the coverslip carefully by hand, the whole animal or a particular appendage could be positioned in different aspects, making possible the observation of morphological details. During the examination water slowly evaporated, and appendages or whole animals eventually remained in completely dry Faure's medium. All drawings were prepared using a drawing attachment (tube) on a Leica-DMLS brightfield compound microscope, with C-PLAN achromatic objectives. Specimens that were not drawn were examined in a mixture of equal parts of distilled water and glycerol and, after examination, were again preserved in 70% ethanol. Samples for the scanning electron microscopy were couted in gold and observed under the LEO FEG VPSEM microscope on the in-lens detectors, with working distances between 2 and 6 mm and accelerating voltages between 2 and 5 kV. All the material is deposited in the Western Australian Museum, Perth (prefix WAM).

Morphological terminology follows Huys and Boxshall (1991), except for the swimming legs armature formula, where a much more simplified version is used.

SYSTEMATICS

Family Cyclopidae Burmeister, 1834

Subfamily Cyclopinae Dana, 1853

Genus *Metacyclops* Kiefer, 1927

Metacyclops kimberleyi sp. nov.
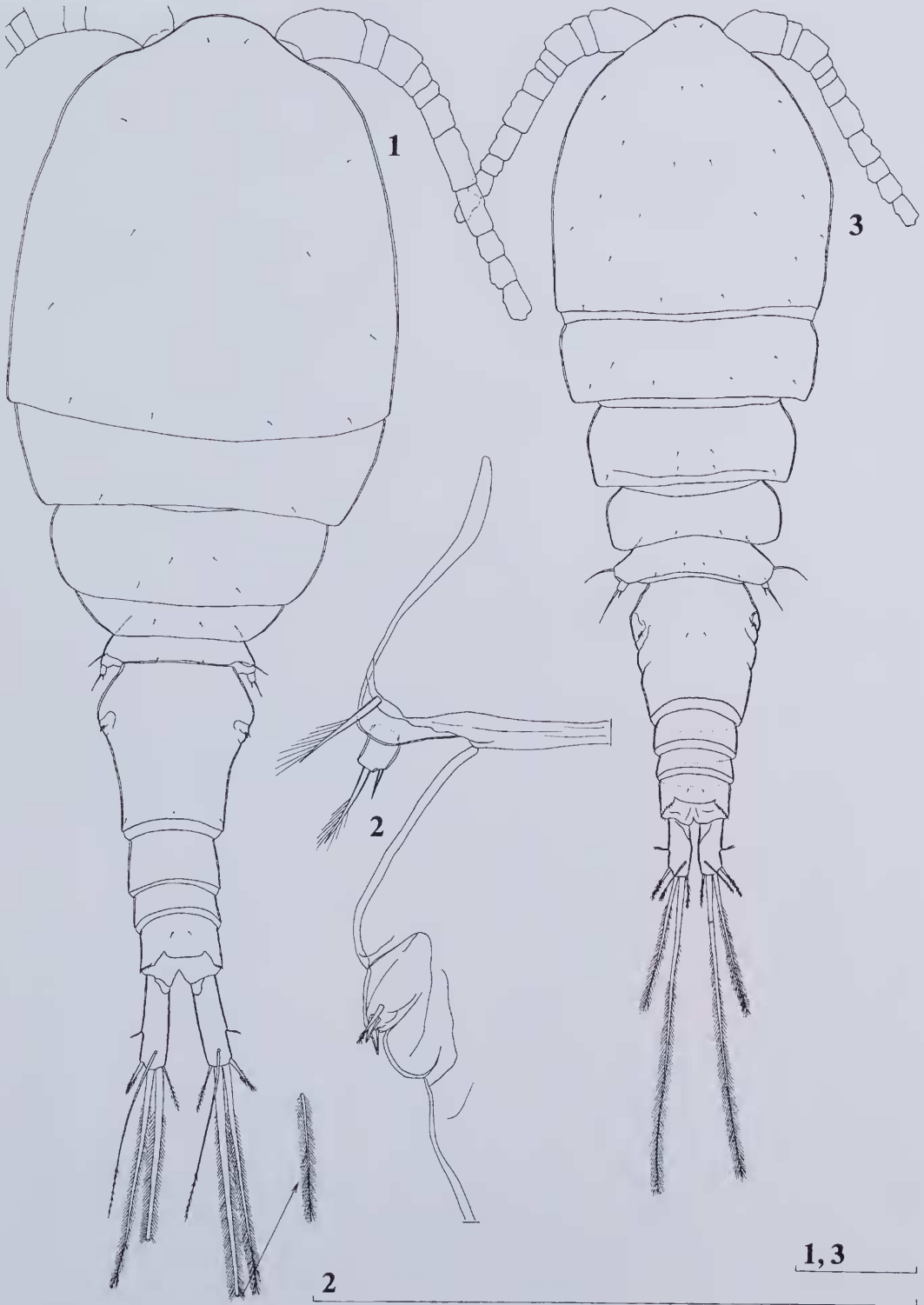Figures 1, 2, 4–28, 46, 48 and 50

Material Examined

Holotype
Female (WAM C28628), Western Australia, Kimberley, Argyle Diamond Mine, groundwater monitoring bore 29D, 16°41'37"S, 128°27'11"E, 10 October 2002, leg. W. F. Humphreys and R. Webb (BES 9693): dissected on two slides.

Allotype
Male (WAM C28629), Western Australia, Kimberley, Argyle Diamond Mine, groundwater monitoring bore 29D, 16°41'37"S, 128°27'11"E, 10 October 2002, leg. W. F. Humphreys and R. Webb (BES 9693): dissected on two slides.

Figures 1–3   *Metacyclops kimberleyi* sp. nov., holotype (female): 1 – habitus, dorsal view; 2 – left fifth and sixth legs, dorsal view; *Metacyclops pilbaricus* sp. nov., holotype (female): 3 – habitus, dorsal view. Scales = 0.1 mm.

Figures 4–8 *Metacyclops kimberleyi* sp. nov., holotype (female): 4 – urosome, ventral view; 5 – antenna; 6 – maxillula, arthrite of praecoxa; 7 – mandibular palp; 8 – maxilla. Scales = 0.1 mm.

Paratypes

Western Australia, Kimberley, Argyle Diamond Mine, groundwater monitoring bore 29D, 16°41'37"S, 128°27'11"E, 10 October 2002, leg. W. F. Humphreys and R. Webb (BES 9693): one female on SEM stub, couted in gold (WAM C28630) + four copepodids in alcohol (WAM C28631).

Other material

Western Australia, Kimberley, Argyle Diamond Mine, groundwater monitoring bore 30S, 16°41'22"S, 128°27'05"E, 10 October 2002, leg. W. F. Humphreys and R. Webb (BES 9699): three copepodids in alcohol (WAM C28632).

Description

Female (holotype). Body length, excluding caudal setae, 0.862 mm. Habitus (Figure 1) robust, with prosome/urosome ratio 1.4 and greatest width at posterior part of cephalothorax. Body length/width ratio about 2.8; cephalothorax almost 2.5 times as wide as genital double-somite. Rostral expansion well developed. Free pedigerous somites without particular expansions laterally. Colour of preserved specimen yellowish. Nauplius eye not visible. Rostrum well developed, membranous, broadly rounded and furnished with two large sensillae. Cephalothorax somewhat longer than wide; represents 40% of total body length. Surface of cephalothorax shield with few large sensillae, smooth (without minute cuticular pits). Whole body very smooth, with only a few sensillae on prosomites. Hyaline fringes of prosomites narrow and smooth. Fifth pedigerous somite ornamented with 2 dorsal large sensillae and 2 lateral ones; hyaline fringe smooth both dorsally and ventrally (Figures 2, 4 and 11). Genital double-somite slightly longer than wide (ventral view), ornamented with 2 large lateral sensillae; hyaline fringe finely serrated both ventrally and dorsally. Copulatory pore very small, rounded, situated at distal end of first third of somite length; copulatory duct narrow, sclerotized and siphon-shaped. Seminal receptacle relatively large, represents 45% of double-somite's length, with clearly divided anterior and posterior expansions; anterior expansion about 1.2 times as long as posterior one (Figures 4 and 11). Ovipores situated dorsolaterally, covered with reduced sixth legs. Third and fourth urosomal somites unornamented, with irregularly serrated fringes both ventrally and dorsally; third somite about 1.6 times as long as fourth somite. Anal somite with smooth, straight, anal operculum, which somewhat produced posteriorly, but not reaching posterior margin of somite; ornamented with 2 large sensillae dorsally and transverse row of spinules on posterior margin (Figures 9 and 15). Anal sinus smooth.

Caudal rami (Figures 4, 9 and 15) slightly divergent, with space between them of about 0.6 of 1 ramus width, and 3.4 times as long as wide; ornamented with few spinules at base of lateral and outermost apical setae, smooth. Dorsal seta very long, about 2.1 times as long as ramus, inserted at 5/6 of ramus length, uniarticulate at base and bipinnate at distal part. Lateral seta arising at 3/5 of ramus length, shorter than ramus width. Outermost apical seta very stout, spiniform, about 0.46 times as long as ramus, bipinnate. Innermost apical seta about 0.26 times as long as dorsal one, and almost 1.2 times as long as outermost apical seta. Principal apical setae without visible braking planes; inner seta about 1.5 times as long as outer one, and 0.34 times as long as body length.

Antennula (Figure 16) 11-segmented, almost reaching posterior margin of cephalothorax, with slender aesthetascs on eighth and eleventh segments and setal formula as follows: 7.4.6.2.2.2.3.2.2.3.7. Just one seta on fourth segment articulating on basal part. One seta on fifth segment spiniform and very short. Just 12 setae (30%) pinnate at distal part (mostly longer and stronger setae); other setae smooth. First segment ornamented with arched row of spinules on anterior surface; other segments with no ornamentation visible. Length ratio of antennular segments, from proximal end and along caudal margins, 1 : 0.3 : 0.5 : 0.2 : 0.15 : 0.4 : 0.9 : 0.7 : 0.3 : 0.4 : 0.5.

Antenna (Figure 5) 4-segmented, comprising relatively large coxobasis and 3-segmented endopod; ornamented with longitudinal rows of minute spinules along posterior margin of endopodal segments. Coxobasis about 2.3 times as long as wide, ornamented with three small groups of minute spinules, armed with 2 smooth setae at distal inner corner; seta representing exopod absent. First endopodal segment armed with 1 smooth seta. Second endopodal segment about twice as long as wide, armed with 6 setae (4 lateral, 1 subapical, and 1 apical). Third endopodal segment about 3 times as long as wide, armed with 7 apical setae. All setae smooth, except longest apical one, which ornamented with short row of minute spinules at midlength.

Labrum (Figure 12) trapezoidal, ornamented with 2 bunches of nearly 30 long and slender spinules on ventral surface. Cutting edge straight, with 13 relatively large teeth between produced sharp lateral corners. No other ornamentation visible.

Mandibula (Figures 7, 10 and 18) with small but distinct palp, armed with 2 very long, finely plumed setae and 1 short, smooth, seta on distal end. Coxal gnathobase cutting edge with very strong teeth and 2 outermost pinnate setae; one seta somewhat longer than neighboring tooth, other much shorter.

Maxillula (Figures 6 and 19) composed of well developed praecoxa and 2-segmented palp. Arthrite
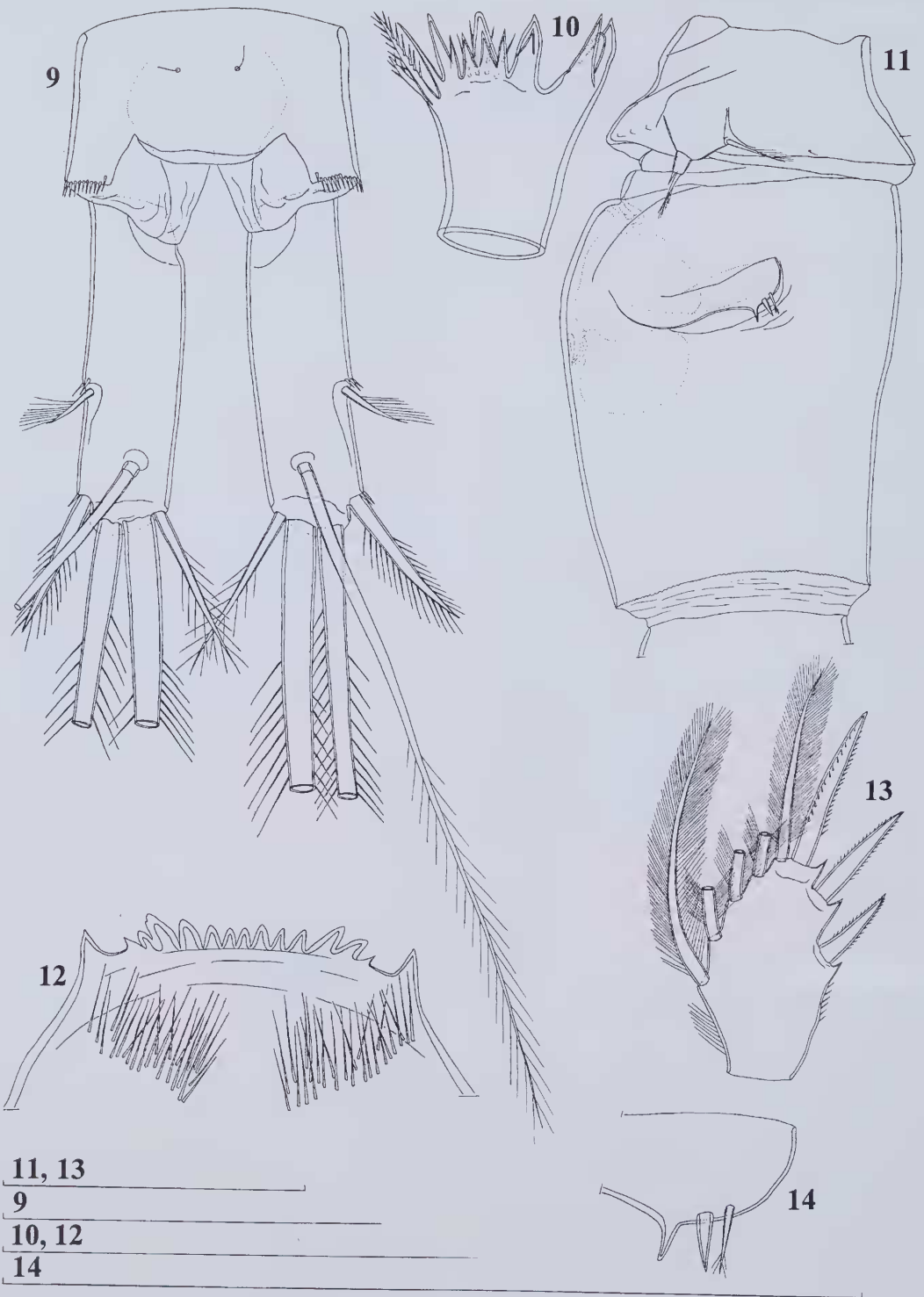
Figures 9–14 *Metacyclops kimberleyi* sp. nov., holotype (female): 9 – anal somite and caudal rami, dorsal view; 10 – mandibula; 11 – fifth pedigerous and genital double-somite, lateral view; 12 – labrum; 13 – second exopodal segment of second swimming leg; 14 – sixth leg, lateral view. Scales = 0.1 mm.
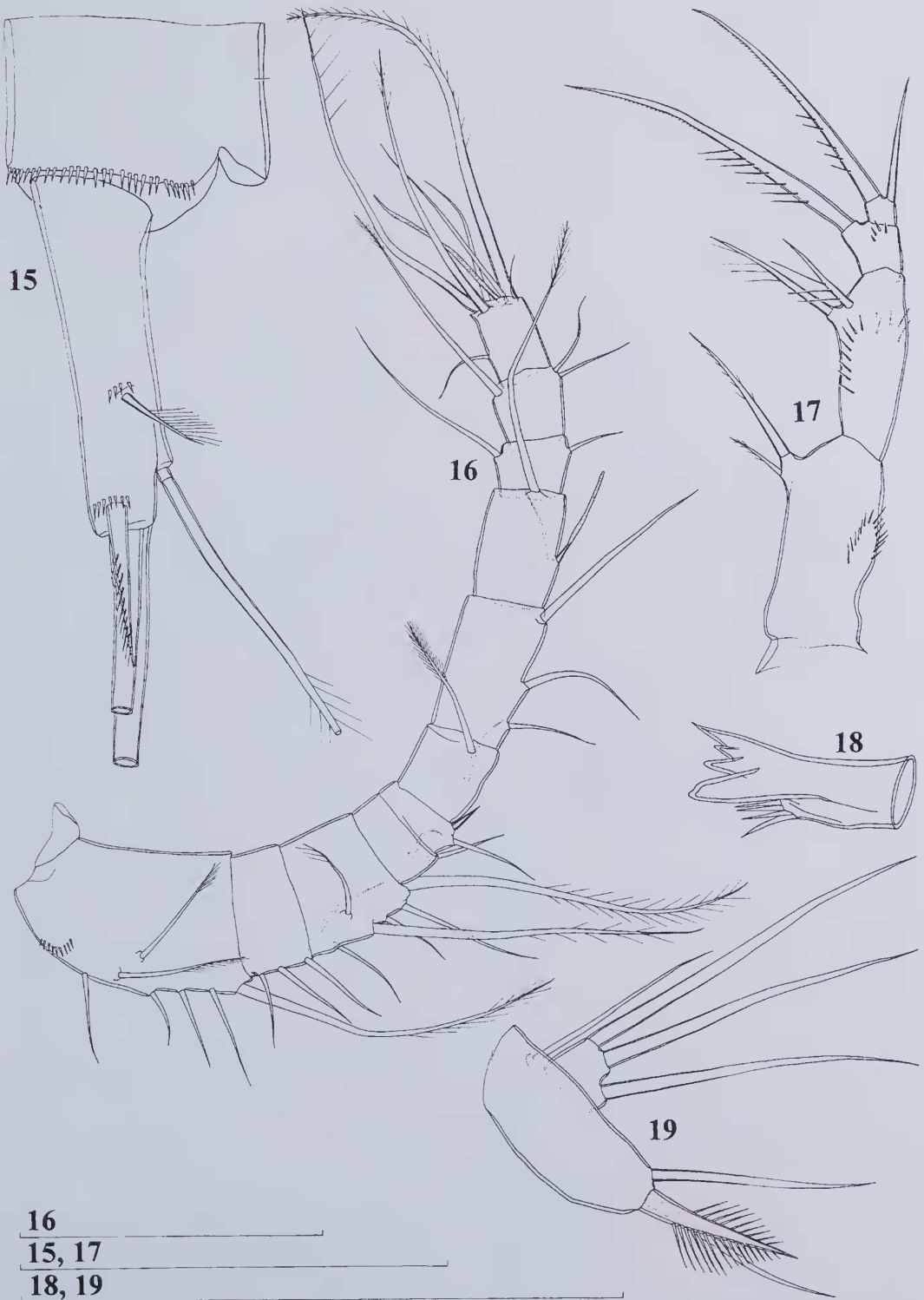
Figures 15–19   *Metacyclops kimberleyi* sp. nov., holotype (female): 15 – anal somite and left caudal ramus, lateral view; 16 – antennula; 17 – maxilliped; 18 – mandibula, coxal gnathobase; 19 – maxillular palp. Scales = 0.1 mm.
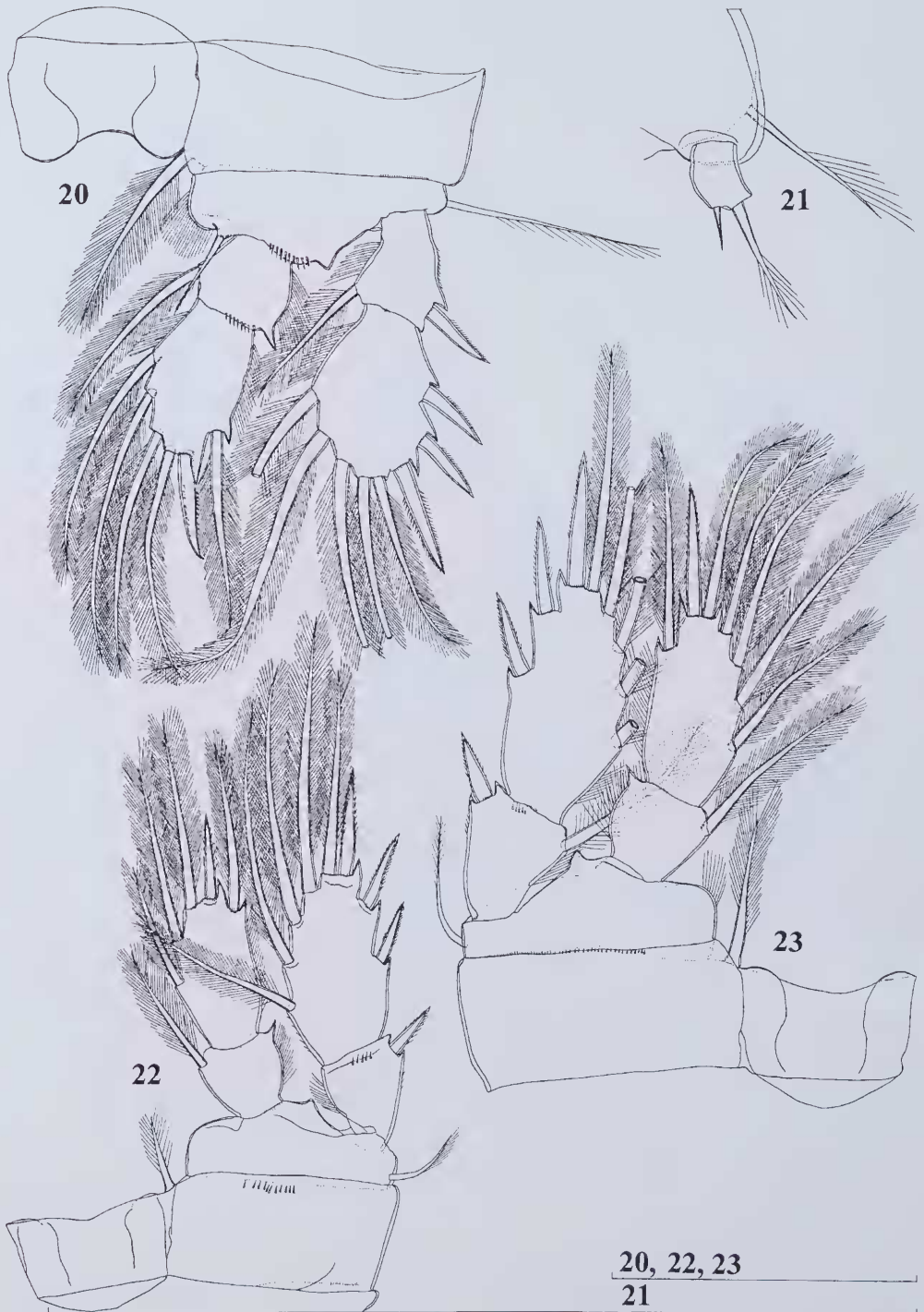
Figures 20–23 *Metacyclops kimberleyi* sp. nov., holotype (female): 20 – first swimming leg; 21 – fifth leg; 22 – fourth swimming leg; 23 – third swimming leg. Scales = 0.1 mm.

of praecoxa with 4 strong apical spines; only 1 distinct and ornamented with 2 setules. Praecoxa armed with 6 armature elements along inner margin, longest one pinnate. Palp with distinct endopod, which bearing 2 apical and 1 lateral smooth setae, and armed laterally with 1 exopodal smooth seta and apically with 2 slender and smooth setae and 1 robust, strongly bipinnate, spine. Margin between endopod and distal part of basis straight.

Maxilla (Figure 8) enormous comparing with other mouth appendages, 5-segmented, but praecoxa fused to coxa on posterior surface, and also partly on anterior surface. No ornamentation visible. Proximal endite of praecoxa elongate, slender, armed with 2 pinnate setae; distal endite short, unarmed. Proximal endite of coxa with 1 bipinnate seta; distal endite highly mobile, elongate, and armed apically with 1 slender and 1 strong and bipinnate seta. Basis expanded into not very robust claw, ornamented with longitudinal row of strong spinules along concave margin (all spinules of about same length), and armed with 2 setae; strong seta as long as claw, pinnate. Endopod 2-segmented; proximal segment armed with 2 robust setae; distal segment with 1 robust and pinnate apical seta and 2 slender and smooth setae. Longest seta on distal endopodal segment slightly longer than strong seta on basis.

Maxilliped (Figure 17) 4-segmented, composed of syncoxa, basis and 2-segmented endopod. Syncoxa ornamented with arched row of spinules on proximal part of outer margin, armed with 2 bipinnate setae; distal seta almost 2.5 times as long as proximal one. Basis 2.3 times as long as wide, ornamented with 1 longitudinal and 1 transverse row of long spinules, and armed with 2 strong unipinnate setae. First endopodal segment ornamented with 4 small spinules, armed with 1 very strong, spiniform and unipinnate, seta. Second endopodal segment without any ornamentation, armed with only 2 apical setae; inner seta twice as long as outer one and 0.8 times as long as seta on first endopodal segment.

All swimming legs with 2-segmented exopods and endopods (Figures 13, 20, 22 and 23). Swimming legs armature formula as follows (legend: inner/outer spine or seta; inner/terminal/outer):

	Exopod		Endopod	
Segments	1	2	1	2
First leg	1/1	3/2/3	1/0	3/2/1
Second leg	1/1	4/2/2	1/0	4/2/1
Third leg	1/1	4/2/2	1/0	4/2/1
Fourth leg	0/1	4/2/2	1/0	3/1/1

Second exopodal segment spine formula: 3.3.3.3. Intercoxal sclerite of all swimming legs with concave distal margins, and without any ornamentation. Coxae of all swimming legs

ornamented with row of spinules along posterior margin (those on fourth leg largest) and armed with plumose seta on distal inner corner (that on fist leg longest, on fourth leg shortest). Relatively slender spine inserted at inner corner of basis of first leg reaching somewhat beyond posterior margin of first endopodal segment. Outer seta on basis of first swimming leg long; those on other legs much shorter; just seta on second leg basis smooth, other setae unipinnate at distal end. All setae on endopods and exopods slender and plumose; no modified setae observed. Second endopodal segment of fourth swimming leg about 1.8 times as long as wide; only apical spine almost twice as short as segment (Figure 22).

Fifth leg (Figures 2, 11 and 21) with basal segment completely fused to somite, with remnant of ancestral separation visible in dorsal view; outer basal seta inserted dorsally on somite and unipinnate at distal part. Distal segment about 1.4 times as long as wide, armed with apical outer seta and subapical inner spine; without any ornamentation. Apical seta on distal segment bipinnate at distal end, about 1.8 times as long as segment, 3 times as long as spine, and about 0.7 times as long as basal seta. Spine on distal segment smooth and 0.6 times as long as segment.

Sixth leg (Figures 2, 11 and 14) indistinct, very small cuticular plate, armed with 2 almost equal, smooth, spines, and 1 slightly longer and bipinnate seta. Median spine distinct, other one completely fused to leg.

Male (allotype). Body length, excluding caudal setae, 0.712 mm. Habitus (Figure 27) slender, with prosome/urosome ratio 1.7 and greatest width at posterior end of cephalothorax. Body length/width ratio about 2.8; cephalothorax about 2.4 times as wide as genital somite. Rostral expansion well developed. Cephalothorax slightly longer than its greatest width; represents 39% of total body length. Ornamentation of prosomal somites, colour, and nauplius eye similar to female. Hyaline fringe of fifth pedigerous somite smooth. Genital somite twice as wide as long, with irregularly serrated hyaline fringe dorsally. Hyaline fringes of other urosomal somites (except anal one) finely serrated both dorsally and ventrally. Anal somite ornamented with 2 large dorsal sensillae and with transverse row of spinules on posterior margin.

Caudal rami (Figure 24) parallel, with space between them less than half of 1 ramus width, and about 3.8 times as long as wide. Armature and ornamentation similar to female.

Antennula (Figures 25 and 26) 15-segmented (ancestral fifth and sixth, as well as sixteenth and seventeenth, segments fused), geniculate, with geniculation between thirteenth and fourteenth segments, longer than cephalothorax. First segment with 3 aesthetascs; 1 aesthetasc present on fourth,
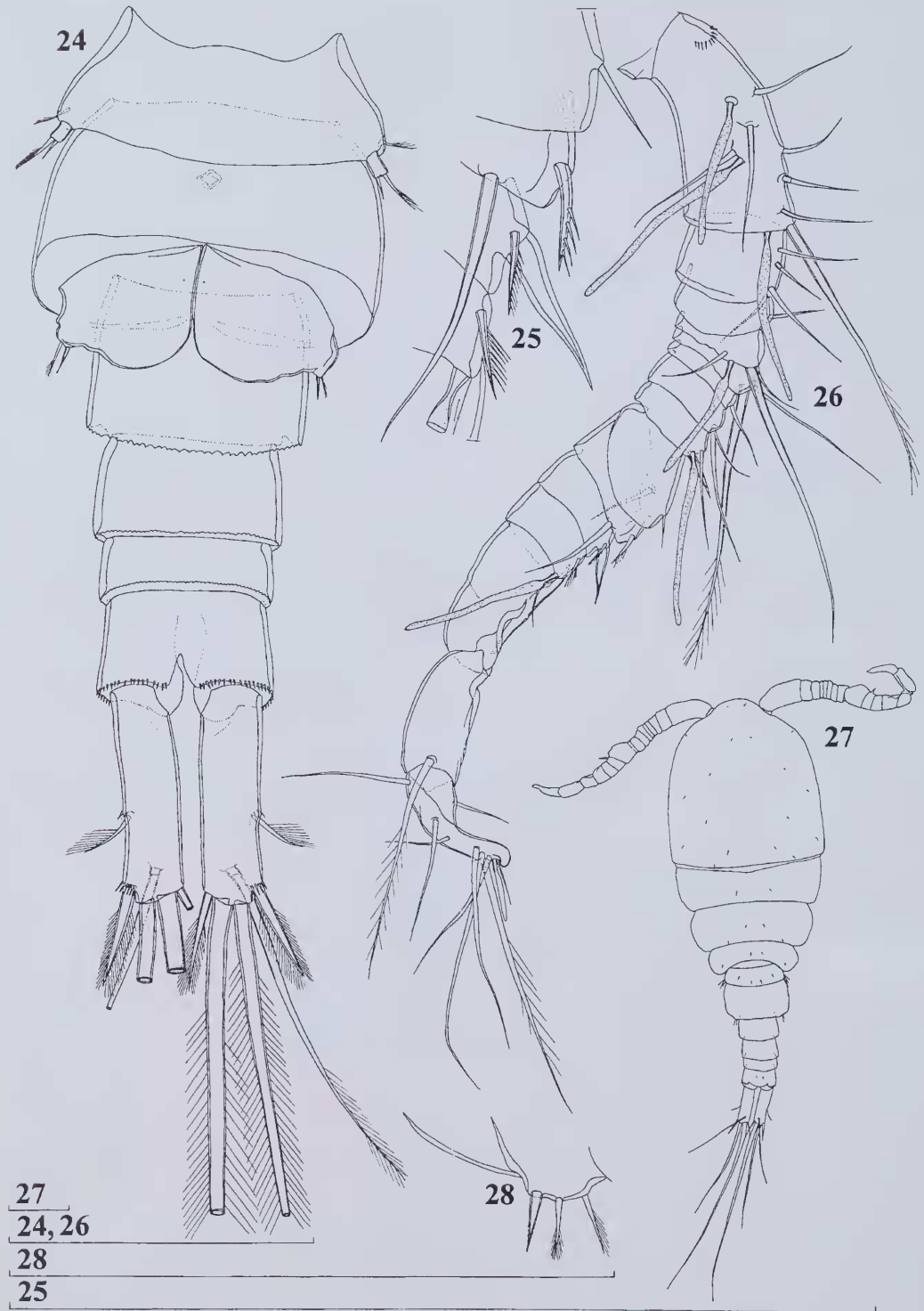
Figures 24–28   *Metacyclops kimberleyi* sp. nov., allotype (male): 24 – urosome, ventral view; 25 – antennula, detail; 26 – antennula; 27 – habitus, dorsal view; 28 – sixth leg, lateral view. Scales = 0.1 mm.

eighth, twelfth, and fifteenth segment. All aesthetascs slender and short. Setal formula as follows: 7.4.1.2.1.2.1.2.2.2.2.2.2.1.1.3.6. Many setae characteristically modified, spiniform. Part of tenth segment as distinct lobe, bearing 1 slender and 1 spiniform seta. Elements of thirteenth and fourteenth and segments typically transformed as log T-shaped plates.

Antenna, labrum, mandibula, maxillula, maxilla, maxilliped and swimming legs similar to female. Second endopodal segment of fourth swimming leg with slightly longer apical spine than in female.

Fifth leg (Figure 24) similar to female. Distal segment about 1.5 times as long as wide, armed with apical outer seta and subapical inner spine; without any ornamentation. Apical seta on distal segment bipinnate at distal end, about 1.8 times as long as segment, twice as long as spine, and as long as basal seta. Spine on distal segment smooth and slightly shorter than segment.

Sixth leg (Figure 28) simple cuticular plate, clearly divided on outer surface, armed with 1 spine and 2 pinnate setae; ornamented with single cuticular pore. Both setae and spine of about same length.

Variability

Besides the holotype and allotype only one additional adult specimen has been collected and studied (both under brightfield compound microscope and scanning electron microscope), although not dissected. That paratype female is slightly shorter than the holotype (0.845 mm), but without any other noticable variation.

Etymology

The name is derived from the region Kimberley (Western Australia) where the species was collected. It is to be treated as a noun in the genitive singular.

Metacyclops pilbaricus sp. nov.
Figures 3 and 29–44

Material Examined

Holotype
Female (WAM C28633), Western Australia, Pilbara, Newman Borefield, groundwater monitoring bore WB 23/4, 23°19'03"S, 119°51'02"E, 23 July 1997, leg. W. F. Humphreys and S. M. Eberhard (BES 4823 and 4829): dissected on two slides.

Paratypes
Western Australia, Pilbara, Newman Borefield, groundwater monitoring bore WB 23/4, 23°19'03"S, 119°51'02"E, 23 July 1997, leg. W. F. Humphreys and S. M. Eberhard (BES 4823 and 4829): two copepodids in alcohol (WAM C28634).

Description

Female (holotype). Body length, excluding caudal setae, 0.7 mm. Habitus (Figure 3) very characteristic, spindle-shaped, with prosome/urosome ratio 1.5 and greatest width at middle of cephalothorax length. Body length/width ratio about 3; cephalothorax about 2.1 times as wide as genital double-somite. Rostral expansion well developed. Free pedigerous somites without particular expansions laterally. Preserved specimen colourless. Nauplius eye not visible. Rostrum well developed, membranous, broadly rounded and furnished with two large sensillae. Cephalothorax slightly longer than wide; represents 34% of total body length. Surface of cephalothorax shield smooth, ornamented only with many large sensillae. Whole body smooth, without any cuticular pits. Hyaline fringes of prosomites narrow and smooth. Fifth pedigerous somite ornamented with 4 dorsal large sensillae; hyaline fringe smooth both dorsally and ventrally (Figure 30). Genital double-somite as long as its greatest width (ventral view), ornamented with 2 large dorsal sensillae; hyaline fringe serrated dorsally and laterally, but smooth ventrally. Copulatory pore small, squeezed and arched, situated at 2/5 of somite length; copulatory duct straight, short, well sclerotized and oriented anteriorly. Seminal receptacle relatively short but broad, represents 30% of double-somite's length, with clearly divided anterior and posterior expansions; posterior expansion approximately 1.5 times as long as anterior one (Figure 30). Ovipores situated dorsolaterally, covered with reduced sixth legs. Third and fourth urosomal somites unornamented and with smooth fringes both ventrally and dorsally; third somite about 1.5 times as long as fourth one. Anal somite with smooth, convex, anal operculum, which somewhat produced posteriorly, but not reaching posterior margin of somite; ornamented with 2 large sensillae dorsally and transverse row of small spinules on posterior margin (Figure 35). Anal sinus smooth.

Caudal rami (Figures 30 and 35) parallel, with space between them less than half of 1 ramus width, and 2.6 times as long as wide; ornamented only with few minute spinules at base of lateral and outermost apical setae. Dorsal seta relatively short, about as long as ramus, inserted at 3/4 of ramus length, uniarticulate at base and pinnate at distal part. Lateral seta arising at midlength of ramus, shorter than ramus width. Outermost apical seta stout, spiniform, about 0.7 times as long as ramus, bipinnate. Innermost apical seta about 0.7 times as long as dorsal one, and 0.8 times as long as outermost apical seta. Principal apical setae without braking planes; inner seta about 2.2 times as long as outer one, and 0.37 times as long as body length. Inner principal apical seta on right ramus with abnormality, probably as consequence of damage during postembryonic development.
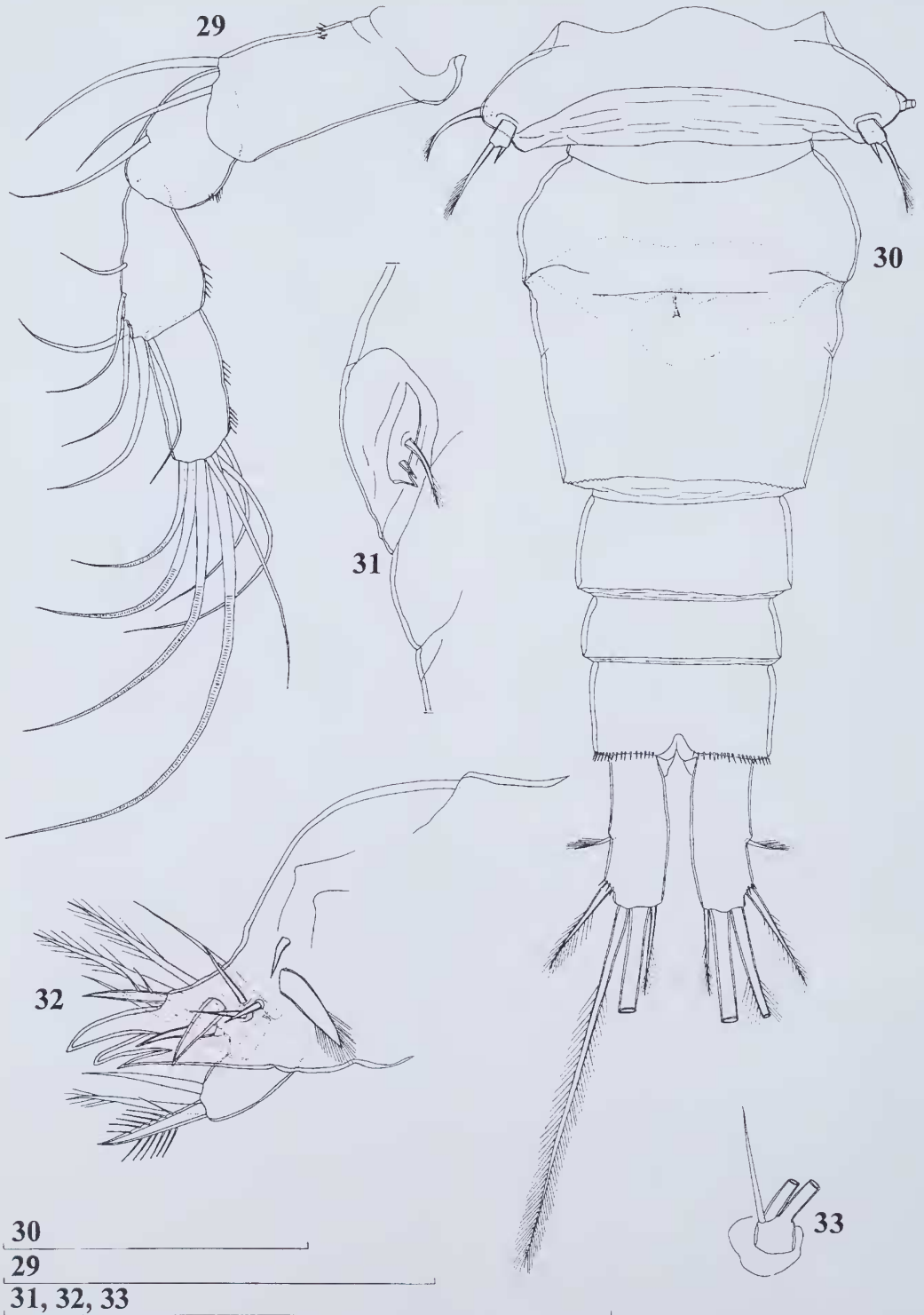
Figures 29–33 *Metacyclops pilbaricus* sp. nov., holotype (female): 29 – antenna; 30 – urosome, ventral view; 31 – sixth leg, dorsal view; 32 – maxillula; 33 – mandibular palp. Scales = 0.1 mm.

Antennula (Figure 34) 11-segmented, not reaching posterior margin of cephalothorax, with slender aesthetascs on eighth and eleventh segments and setal formula as follows: 7.4.6.2.2.2.3.2.2.3.7. One apical seta on eleventh segment articulating on basal part. One seta on fifth segment spiniform and very short. Just 2 setae on first segment, 1 on third, 1 on tenth and 3 setae on eleventh segment pinnate at distal part; all other setae smooth. First segment ornamented with short semitransverse row of spinules on anterior surface; other segments with no ornamentation visible, except cuticular pits. Length ratio of antennular segments, from proximal end and along caudal margins, 1 : 0.4 : 0.6 : 0.4 : 0.2 : 0.6 : 1 : 0.9 : 0.5 : 0.7 : 0.8.

Antenna (Figure 29) 4-segmented, comprising short coxobasis and 3-segmented endopod; ornamented with longitudinal rows of minute spinules on endopodal segments. Coxobasis relatively long, ornamented also with few spinules anterior surface, armed with 2 smooth setae at distal inner corner (without seta representing exopod). First endopodal segment armed with 1 smooth seta. Second endopodal segment about 1.5 times as long as wide, armed with 6 setae (4 lateral, 1 subapical, and 1 apical). Third endopodal segment twice as long as wide, armed with 7 apical setae. All setae smooth.

Labrum (Figure 36) trapezoidal, ornamented with 2 bunches of 14 long and slender spinules on ventral surface. Cutting edge straight, with 12 relatively strong and blunt teeth between produced sharp lateral corners. No other ornamentation visible.

Mandibula (Figure 33) with small but distinct palp, armed with 2 very long, finely plumed setae and 1 short, smooth, seta on distal end. Coxal gnathobase cutting edge with very strong teeth and outermost pinnate seta, which shorter than short seta on palp.

Maxillula (Figures 32) composed of well developed praecoxa and 2-segmented palp. Arthrite of praecoxa with 4 strong apical spines; only 1 distinct and ornamented with 2 setules. Praecoxa armed with 7 armature elements along inner margin, longest one pinnate. Palp with completely divided endopod, which bearing 2 apical pinnate and 1 lateral smooth setae, and armed laterally with 1 exopodal smooth seta and apically with 2 slender setae (1 pinnate, other smooth) and 1 robust, strongly bipinnate, spine. Margin between endopod and distal part of basis without particular expansions.

Maxilla (Figure 37) unornamented, 5-segmented, but praecoxa fused to coxa on posterior surface, and also partly on anterior surface. Proximal endite of praecoxa elongate, armed with 2 pinnate setae, distal endite small, unarmed. Proximal endite of coxa with 1 strong, bipinnate, seta; distal endite

highly mobile, elongate, and armed apically with 2 subequal pinnate setae. Basis expanded into robust claw, ornamented with longitudinal row of strong spinules along concave margin (proximalmost spinules shortest), and armed with 2 setae; strong seta as long as claw, pinnate. Endopod 2-segmented; proximal segment armed with 2 robust setae; distal segment with 1 robust apical seta and 2 slender subapical setae; all setae on endopod smooth. Longest seta on distal endopodal segment as long as strong seta on basis.

Maxilliped (Figure 43) 4-segmented, composed of syncoxa, basis and 2-segmented endopod. Syncoxa ornamented with arched row of spinules on proximal part of outer margin, armed with 3 setae; middle setae strongest and longest, 1.36 times as long as proximal one, and about twice as long as distal seta; distalmost seta smooth, other 2 unipinnate. Basis 1.2 times as long as wide, ornamented with 1 longitudinal and 1 transverse row of long spinules on inner side and 1 row of spinules on outer distal corner; armed with 2 strong pinnate setae. First endopodal segment ornamented with transverse row of spinules along posterior margin; armed with 1 strong spiniform seta. Second endopodal segment without any ornamentation, armed with 2 smooth and 1 pinnate spiniform seta. Strongest seta on second endopodal segment about 1.2 times as long as seta on first endopodal segment.

All swimming legs with 2-segmented exopods and endopods (Figures 39, 40, 41 and 42). Swimming legs armature formula as follows (legend: inner/outer spine or seta; inner/terminal/outer):

	Exopod		Endopod	
Segments	1	2	1	2
First leg	1/1	3/2/3	1/0	3/2/1
Second leg	1/1	4/2/2	1/0	4/2/1
Third leg	1/1	4/2/2	1/0	4/2/1
Fourth leg	0/1	4/2/2	1/0	3/1/1

Second exopodal segment spine formula: 3.3.3.3. Intercoxal sclerite of all swimming legs with deeply concave distal margins, and without any ornamentation. Coxa of fourth swimming leg ornamented with 2 row of spinules; coxae of other swimming legs with only 1 row of spinules each. All coxae with long and plumose seta on distal inner corner, except on fourth leg, where that seta is smooth and spiniform. Spine inserted at inner corner of basis of first leg reaching distal margin of second endopodal segment. Outer seta on basis of first swimming leg very long; those on other legs much shorter; just seta on second leg basis smooth, other setae pinnate at distal end. All setae on endopods and exopods slender and plumose; no modified setae observed. Second endopodal segment of fourth swimming leg about 1.6 times as long as wide; only apical spine about 0.85 times as long as segment (Figure 41).
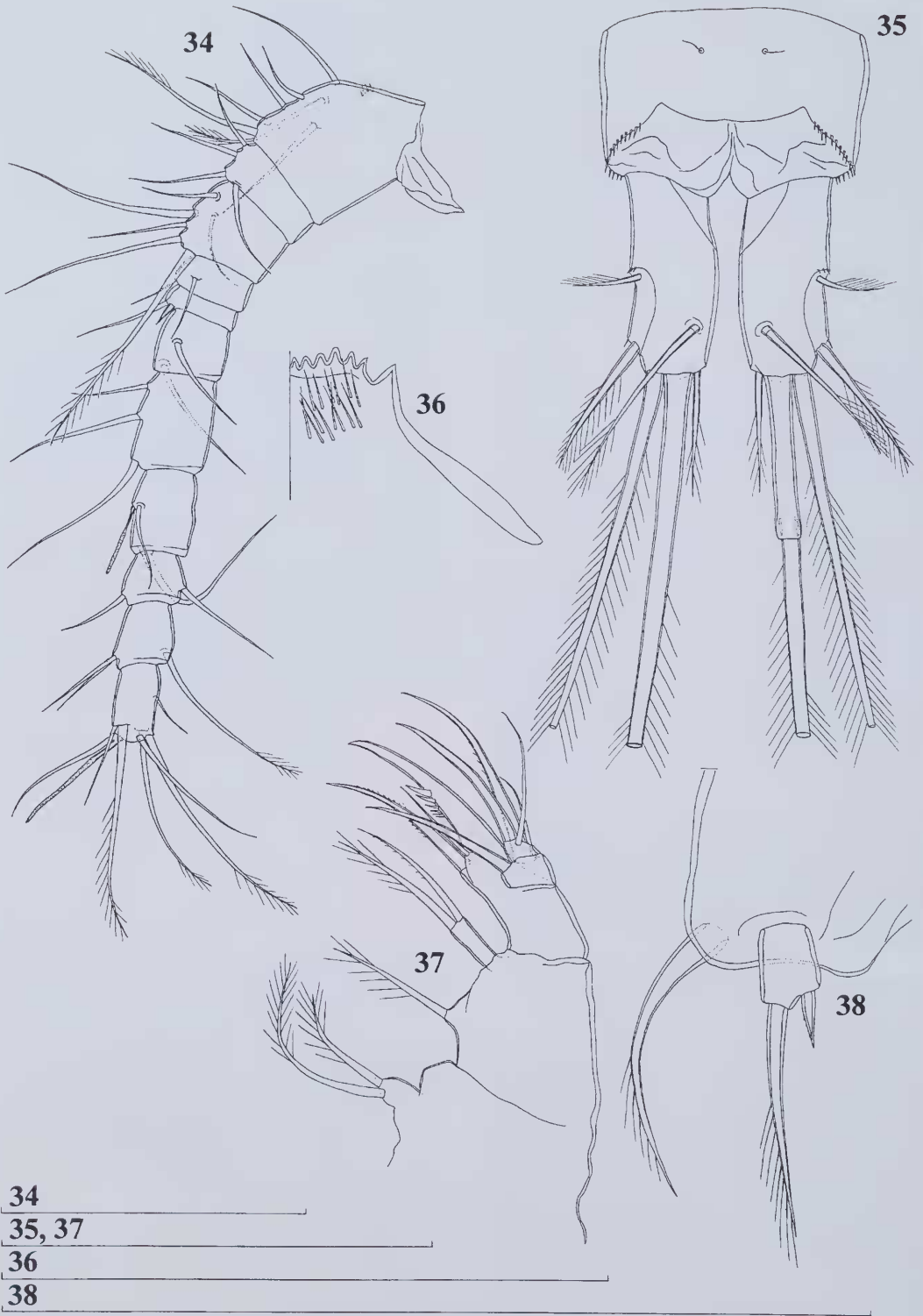
Figures 34–38   *Metacyclops pilbaricus* sp. nov., holotype (female): 34 – antennula; 35 – anal somite and caudal rami, dorsal view; 36 – labrum, left half; 37 – maxilla; 38 – fifth leg, ventral view. Scales = 0.1 mm.
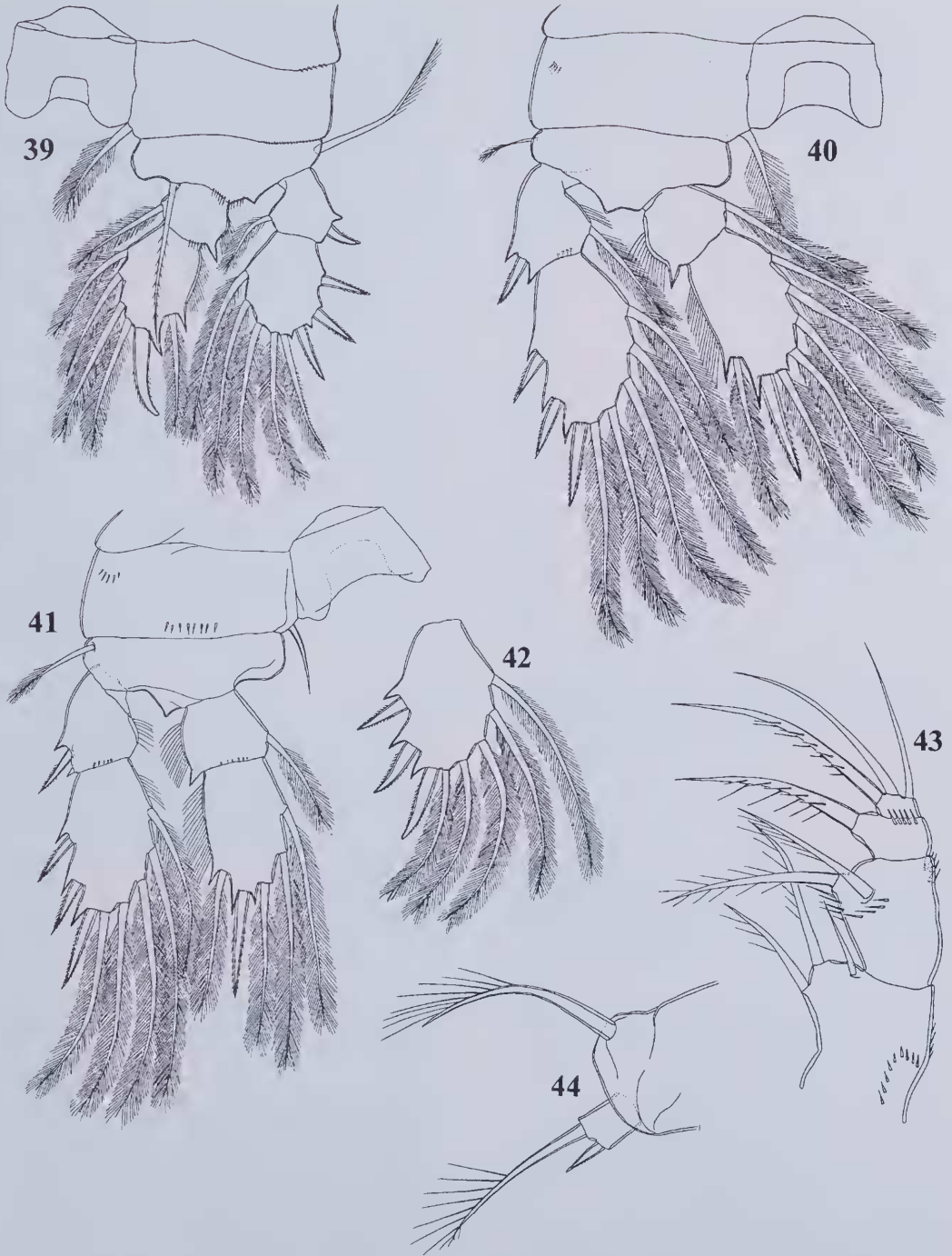
Figures 39–44 *Metacyclops pilbaricus* sp. nov., holotype (female): 39 – first swimming leg; 40 – third swimming leg; 41 – fourth swimming leg; 42 – second exopodal segment of second swimming leg; 43 – maxilliped; 44 – left fifth leg, dorsal view. Scales = 0.1 mm.

Figure 45   Distribution of the Australian representatives of the genus *Metacyclops*, with the proposed phyletic three of the "*trispinosus*"-group: 1 – *M. arnaudi* (Sars, 1908); 2 – *M. mortoni* Pesce, De Laurentiis and Humphreys, 1996; 3 – *M. laurentiisae* Karanovic, 2004; 4 – *M. pilanus* Karanovic, 2004; 5 – *M. superincidentis* Karanovic, 2004; 6 – *M. pilbaricus* sp. nov.; 7 – *M. kimberleyi* sp. nov. Note: one dot sometimes represents more than one locality.

Fifth leg (Figures 30, 38 and 44) with basal segment completely fused to somite, with remnant of ancestral separation visible in dorsal view; outer basal seta inserted dorsally on somite and unipinnate at distal part. Distal segment about 1.4 times as long as wide, armed with apical outer seta and subapical inner spine; without any ornamentation. Apical seta on distal segment unipinnate at distal end, about 2.7 times as long as segment, 4.2 times as long as spine, and about 0.8 times as long as basal seta. Spine on distal segment strong and 0.65 times as long as segment.

Sixth leg (Figure 31) indistinct, very small cuticular plate, armed with 2 almost equal long, smooth, spines, and 1 pinnate and much longer seta. Median spine distinct, other one completely fused to leg.

Male. Unknown.

Variability

Only one female was collected and studied, and it appears to be without any significant asymmetries, apart from the abnormal inner principal apical seta on the right caudal ramus (Figure 35).

Etymology

The name is derived from the region Pilbara (Western Australia) where the species was collected. It is to be treated as a latinized adjective in the nominative singular, agreeing in gender with the masculine generic name.

DISCUSSION

About 60 different species and subspecies are presently known to be members of the genus
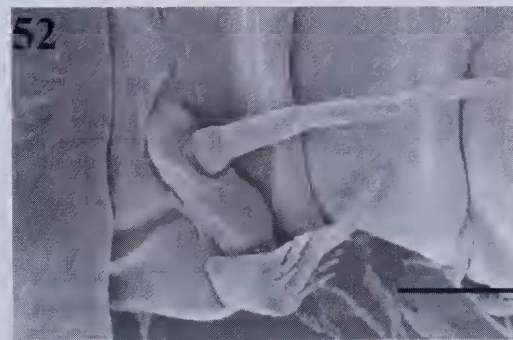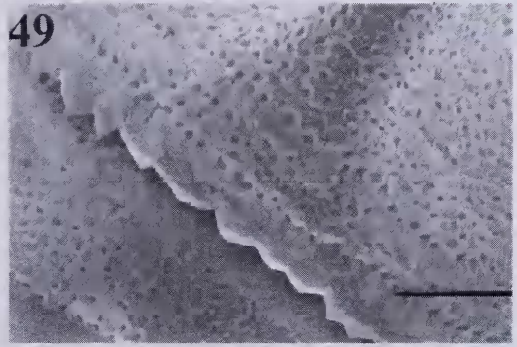
Figures 46–53 Scanning electron micrographs of two Australian *Metacyclops*: 46 – *M. kimberleyi*, female, right caudal ramus dorsally (scale = 11 μm); 47 – *M. laurentiisae*, female, caudal rami dorsally (scale = 9 μm); 48 – *M. kimberleyi*, female, genital double–somite, posterior margin dorsally (scale = 6 μm); 49 – *M. laurentiisae*, female, genital double-somite, posterior margin dorsally (scale = 14 μm); 50 – *M. kimberleyi*, female, part of antennula (scale = 17 μm); 51 – *M. laurentiisae*, female, part of antennula (scale = 21 μm); 52 – *M. laurentiisae*, male, part of antennula (scale = 6 μm); 53 – *M. laurentiisae*, female, anal somite laterally (scale = 14 μm).
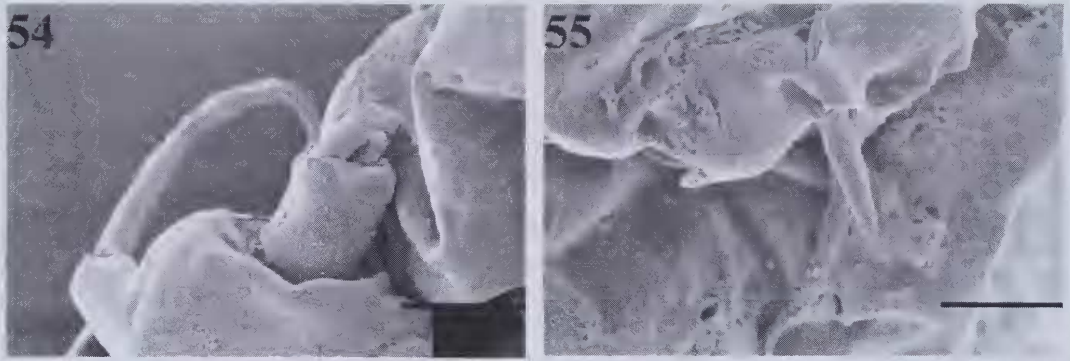
Figures 54–55   Scanning electron micrographs of *Metacyclops laurentiisae*: 54 – female, fifth leg ventrally (scale = 10 μm); 55 – female, sixth leg laterally (scale = 4.3 μm).

Metacyclops, but the real systematic position for many of those remains elusive owing to the standards of description at the time they were described (Karanovic, 2004). Many morphological features within the genus are extremely different, which raises the question as to its monophyly and validity. The antennula, for example, can be composed of nine, ten, 11, 12, or even 17 segments (although in a majority of species it is composed of 11 or 12 segments), and second endopodal segment of the fourth swimming leg can be armed apically with one or two spines, or even with just one seta, or one seta and one spine. The shape of the fifth leg also differs markedly between species, but because this appendage is very small and difficult to describe it has often been underused in species descriptions, despite its general shape being one of the main generic features (Figure 54). It is highly possible that a more detailed examination of the fifth leg, along with many other currently neglected characters, will result in splitting the genus *Metacyclops* into several different genera. Fiers (2001) took an initial step it that direction, when he transferred two Australian species into a separate new genus. Recently I have established a new genus (Karanovic, 2004) to accommodate another Australian species: *M. fiersi* De Laurentiis, Pesce and Humphreys, 2001. In contrast Plesa (1981) attempted to unite the three genera *Apocyclops* Lindberg, 1942, *Psammophilocyclops* Fryer, 1956, and *Metacyclops* Kiefer, 1927, as subgenera of the genus *Metacyclops*, but without sufficient justification (see Reid, 1987; Karanovic, 1999). A proper revision of the genus *Metacyclops*, with careful reexamination (especially details of the antennulae, antennae and mouth appendages armature) and redescription of many species is certainly needed before phylogenetic studies can be conducted.

However, one group of species seems to be not only an easily recognizable morphological group, but a phyletic group as well. It has a clear Eastern Gondwana connection (Africa, India, Australia and New Zealand) and I named it the *"trispinosus"*-group (Karanovic, 2004) after *M. trispinosus* Dumont, 1981, because this species' name contains the main distinguishing character: only three spines on the second exopodal segment of all the swimming legs. Besides the African *M. trispinosus*, which was described by Dumont (1981), the *"trispinosus"*-group also includes the following five species: *M. arnaudi* (Sars, 1908) from Australia (Sars, 1908); *M. laurentiisae* Karanovic, 2004 also from Australia (Karanovic, 2004); *M. margaretae* (Lindberg, 1938) from India (Lindberg, 1938); *M. monacanthus* (Kiefer, 1928) from New Zealand (Kiefer, 1928); and *M. pilanus* Karanovic, 2004 from Australia. The new species described in the present paper also belong to this group, which means that Australia is the centre of diversity (with five out of eight species), although this could be a collecting bias. Two apical spines on the endopod of the fourth swimming leg is a symplesiomorphy of the African *M. trispinosus* and Indian *M. margaretae*, which also share relatively short and subequal principal apical setae on the caudal rami. Both these species are surface water inhabitants (see Lindberg, 1938; Dumont, 1981). All other species of the *"trispinosus"*-group have an apomorphic endopod of the fourth leg, with just one apical spine. They are all Australian species, except *M. monacanthus* which was described from the Lake Ellesmere near Christchurch in New Zealand (Kiefer, 1928). This latter species is also a surface water inhabitant and is only partially described. Unfortunately, we know nothing about its antenna or mouth appendages, although I believe they are very similar to those of *M. arnaudi* since Kiefer (1928) wrote: "*Cyclops monacanthus* nov. spec. besitzt eine auffallende, ohne Zweifel auf Verwandtschaft beruhende Ähnlichkeit mit *C. arnaudi* Sars". However, a detailed redescription of this species is necessary before it can be further discussed phylogenetically.

Of the five Australian species of the "*trispinosus*"-group, only one, *M. arnaudi*, is a surface water inhabitant. As previously mentioned, this species was described from a swamp at St. Arnaud in Victoria by Sars (1908). It is morphologically very similar, and probably phylogenetically very close, to two sympatric subterranean species from the Murchison Region: *M. laurentiisae* and *M. pilanus*. They all share a plesiomorphic antenna morphology, with the exopod present and the second endopodal segment with the full armature (nine setae). As depicted on the proposed phyletic tree for the "*trispinosus*"-group (Figure 45) I assume that *M. arnaudi* has separated earlier from the common ancestor than *M. laurentiisae* and *M. pilanus*, but this may not necessarily be the case and probably only an molecular analysis could give us a more accurate answer. These three species can be distinguished from each other only by details in their habitats and caudal rami shape. The two new species, on the other hand, have an antenna without an exopod and the second endopodal segment with only six setae, which is a synapomorphy that separates them at once from the three other representatives of this group in Australia. *Metacyclops kimberleyi* sp. nov. is distinguished from other members of the group by at least two autapomorphies: the exceptionally long dorsal seta on caudal rami (Figure 9) and the maxilliped with only seven armature elements (Figure 17). It differs from *M. pilbaricus* sp. nov. also by the habitus shape from dorsal view (Figures 1 and 3), seminal receptacle (Figures 4 and 30), caudal rami shape (Figures 9 and 35) and the fifth leg (Figures 21 and 38). *Metacyclops kimberleyi* has enormous maxillae (Figure 8), which extend far away from the body, although there is nothing unusual in the morphology of these conservative appendages other than their size. This may be one of the preadaptations for a predatory way of life, which may be further supported by its robust habitus and large body (for a subterranean species) and also by the morphology of the maxilliped, which is equipped with fewer but much stronger setae and looks like a more powerful grasping organ than in other members of the "*trispinosus*"-group. *Metacyclops pilbaricus* can be distinguished from each member of the group by a number of characters, but the only clear autapomorphy of this species is its unusual body shape (Figure 3), which is more harpacticoid-like (without very obvious distinction between prosome and urosome). It should be also noted here that both *M. kimberleyi* and *M. pilbaricus* have a very smooth surface of all somites and appendages (Figures 46, 48 and 50), while *M. laurentiisae* and *M. pilanus* have numerous cuticular pits (Figures 46, 49, 51 and 53). The situation of this character is not known in *M. arnaudi*. Although there is little doubt that the five Australian representatives of the "*trispinosus*"-group share a common ancestor, the phylogenetic position of this group within the genus *Metacyclops*, as well as the position of the other two Australian *Metacyclops*, is currently unclear. These questions are not always easy to answer even in groups where we have a full set of morphological, physiological, behavioral, ecological and molecular characters, so they would need to wait until at least a proper morphological revision of the genus *Metacyclops* can be presented.

As the genus *Metacyclops* in Australia already has seven valid species, a key to aid in their identification is presented below as well as a map of their distributions (Figure 45).

Key to the Australian *Metacyclops* species

1. Swimming legs with second exopodal segment spine formula 3.3.3.3 3

   Spine formula different 2

2. Spine formula 3.4.4.3 ....
   .... *M. superincidentis* Karanovic, 2004

   Spine formula 3.4.4.2 ....
   .... *M. mortoni* Pesce *et al.*, 1996

3. Exopod of antenna present; second endopodal segment with 9 setae 4

   Exopod of antenna absent; second endopodal segment with 6 setae 6

4. Caudal rami not more than 4 times as long as wide 5

   Caudal rami about 7 times as long as wide ......
   .... *M. arnaudi* (Sars, 1908)

5. Dorsal seta on caudal ramus shorter than outermost apical one ....
   .... *M. laurentiisae* Karanovic, 2004

   Dorsal seta longer than outermost apical one ..
   .... *M. pilanus* Karanovic, 2004

6. Dorsal seta on caudal ramus about as long as ramus .... *M. pilbaricus* sp. nov.

   Dorsal seta more than twice as long as ramus .
   .... *M. kimberleyi* sp. nov.

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